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Cloud Properties Over the North Slope of Alaska and their Dependence on Land Surface Interactions

Goals

There are reasons to expect significant differences between cloud properties at coastal and inland sites at the North Slope of Alaska (NSA). The main goal of this project is to test this hypothesis by using ARM instruments to construct a climatology of cloud optical depths and liquid water paths at Barrow and Atqasuk, which are coastal and inland sites, respectively, at ARM's NSA Cloud and Radiation Testbed (CART). The climatology will include means and distributions about the means of both quantities; the distributions of liquid water paths are especially important because they have been shown to contribute significantly to biases in albedo calculations introduced by plane parallel cloud assumptions in radiative modeling. The climatology will extend over the May-August time period, when there are marked contrasts between the surface properties of inland and coastal or offshore sites. A second goal is to develop a corresponding description of the surface conditions and ambient winds during the same time period to try to relate the cloud characteristics at the two sites to the prevailing meteorological and surface conditions. The third goal is to evaluate and help improve the performance of general circulation models (GCMs) in the region by comparing our data with output obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF) GCM and from the Arctic Regional Climate System Model, and use these comparisons to help identify reasons for discrepancies between the models and data. The comparisons will help determine how well "point" measurements of cloud properties obtained at Barrow and/or Atqasuk can provide a sufficient basis for evaluating and calibrating single column models or cloud ensemble models over the North Slope.

Accomplishments

- Completed first season of data collection (1999) at Barrow and Atqasuk with both microwave radiometer (MWR) and multifilter rotating shadowband radiometer (MFRSR).
- Began second season of data collection at the North Slope, with instruments installed early enough to capture snow melt period.
- Installed and currently operating a sonic anemometer on one of the Barrier Islands near Barrow to measure sensible heat fluxes over the adjacent ocean. A scintillometer is also collecting heat flux data at Atqasuk.
- Carried out initial comparisons of cloud properties at Barrow (1999) and the SHEBA ice station (1998) for the months May-August.
- Carried out initial comparisons of cloud properties at Barrow and Atqasuk (1999) as well as comparisons with ECMWF predictions for the two sites.
- In response to criticisms of the performance of the ARM MWR in Arctic environments, have contributed to an assessment of the MWR's suitability for our studies at Barrow and Atqasuk.

- Published paper in *Journal of Geophysical Research* on the effects of land-use differences on atmospheric stability in prestorm environments, one of the remaining tasks from previous studies at the SGP CART.
- Submitted paper to the *Journal of Climate* on the relative importance of land use differences and topography on wind divergence patterns at the SGP CART.

Progress and Accomplishments

The past twelve months marked a major transition from our previous work at the SGP CART site to our current emphasis on the North Slope of Alaska CART. In the summer of 1999, the Atqasuk site became functional, although full operational readiness was not completed until this year. As part of the initial measurements at Atqasuk, an ARM MFRSR and MWR were set up. The MWR produced useful data for most of the period June through September; the MFRSR became operational somewhat later than the MWR and had to be shut down and rechecked after dust from nearby roads apparently coated the instrument's inlet optics. When this problem had been fixed, the MFRSR at Barrow went off line when construction around the site resulted in a severed cable. The result is that it is possible to do a reasonably complete comparison of MWR data at Barrow and Atqasuk for June through September but a similar comparison of MFRSR data will be limited to a much shorter time period.

This year the same two sets of instruments are again operational at Barrow and Atqasuk, and data have been collected from both since approximately mid-May. Thus far, data collection appears to be good so that there should be an extensive data set available for analysis at the end of this summer. Comparisons with some of the MWR results from 1999 will be possible but this will be the first season with complete, or nearly complete, MFRSR data. This year we may end the data analysis period somewhat earlier than last because the limited sunlight in September means that the MFRSR can only be used for short amounts of time as the summer ends.

In the summer of 1999 a scintillometer was installed and operated at Atqasuk for part of the summer to collect heat flux data from the area. This year the instrument was again installed at Atqasuk but was brought up to full operation significantly earlier than last year. In addition, a sonic anemometer has been installed on Doctor's Island off the coast near Barrow. A tower was installed on a grounded barge on the low-lying island, giving an excellent fetch for the measurement of fluxes for the prevailing wind directions at the site. The sonic's data are communicated via radio modem to the ARM facility at Barrow from which they can be downloaded via the Internet to PNNL. Power for the installation is provided through a combination of batteries and solar panels. We hope to be able to relate some of the cloud properties at Barrow to the fluxes coming off the upwind fetches of ice or open water. A similar purpose would be served by the flux data provided by the scintillometer at Atqasuk, although it will be more of a challenge to interpret the fluxes from the heterogeneous surface of the tundra.

Because a full season of data from Atqasuk and Barrow will not be available until later this year, we have taken advantage of the fact that ARM also had a MWR and a MFRSR at the SHEBA ice camp. Thus, we have carried out a comparison of the distributions of liquid water paths, cloud optical depths, and effective cloud droplet radii at SHEBA (in 1998) and Barrow (in 1999). (We have also been able to look at the cloud optical depths at Barrow for 1998 but very little MWR

data area are available from that year.) The comparison shows that the properties of the clouds are substantially different, with the SHEBA station being characterized by clouds with greater optical depth, greater liquid water paths, but smaller effective droplet radii than was the case for Barrow the succeeding year. These findings have implications for modeling the radiative properties of the clouds at the two sites and it will be interesting to see how successful models are in doing so.

Based on the limited data set available to us from Barrow and Atqasuk in 1999, we have carried out an analysis of the cloud properties at those two sites as well. The cloud properties seem to differ depending on the direction of the ambient winds. For example, for general onshore winds (directions of 315° to 75°) at the 960 mb level, the median values of the liquid water paths of the clouds at Barrow and Atqasuk are similar. For offshore winds (135° to 270°), the Barrow clouds appear to have similar properties but the Atqasuk clouds have significantly less water content. The ECMWF model fails to capture these features. Instead, the model shows little difference between the two sites for either set of directions. Moreover, the model underestimates the liquid water path in both cases. It also predicts wetter clouds for offshore winds, which is not what was observed. These results are still preliminary and a more extensive analysis will be performed when the second season's data from the MWR become available at the end of this summer.

During the past year the ARM MWR has been the subject of some criticism, based on a comparison of MWR and aircraft-derived liquid water paths on several days during the SHEBA campaign. As a result, the approach used in these comparisons has been reexamined, and new retrievals of liquid water paths provided by NOAA/ETL have been used to assess the performance of the ARM MWR. It was concluded that for the purposes of our study, the ARM instrument is both useful and reliable. Some suggested improvements in the retrieval procedures may affect MWR results in selected cases but for the statistical summaries of the type carried out thus far, for comparisons of cloud properties between sites, and for comparisons of the ECMWF model performance with observations during the warmer months of the year, the ARM MWR data should be fine.

Work was also completed on two papers covering topics related to the effects of surface inhomogeneities on boundary layer and cloud properties that could affect the performance of GCMs or SCMs at the SGP CART site. Our findings have sparked considerable controversy in some quarters and there was some delay involved with getting the first paper published in the *Journal of Geophysical Research*. The results indicate that in the SGP CART, resolving subgrid-scale land use differences is unlikely to modify the calculated atmospheric stability sufficiently to affect the likelihood of deep convection as represented by typical indicators such s CAPE. In a second paper, we formed composites of wind fields classified according to season, time of day, and wet or dry periods to isolate the effects of land use patterns on the surface divergence fields over the SGP CART. We found the results to be generally negligible except perhaps for one region of the CART. Topographic influences, in contrast, appeared to be more important despite the small terrain relief in the area. A paper describing these results has been submitted to the *Journal of Climate* and is currently under review.

Refereed Publications

Doran, J.C., and S. Zhong, 2000. A Study of the Effects of Subgrid-Scale Land Use Differences on Atmospheric Stability in Prestorm Environments. *J. Geophys. Res.*, **105**, 9381-9392.

Shaw, W.J., and J.C. Doran, 2000. Observations of Systematic Divergence Patterns and their Relationship to Land use and Topography. Submitted to *Journal of Climate*.

Extended Abstracts

Doran, J.C., J.C. Barnard, S. Zhong, and C.J. Jakob, 2000. Cloud Optical Depths and Liquid Water Paths at the NSA CART. Presented at the Tenth ARM Science Team Meeting.

Status of Previously Submitted Papers

The JGR paper listed under item 7 above had been submitted in the previous year but addressing reviewers' comments delayed publication for a considerable time.

Sonic anemometer, radio modem, and solar panel on Doctor’s Island near the NSA CART at Barrow, AK.